Designation: B488 – 11

Standard Specification for Electrodeposited Coatings of Gold for Engineering Uses[1]

This standard is issued under the fixed designation B488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers requirements for electrodeposited gold coatings that contain not less than 99.00 mass % gold and that are used for engineering applications.

1.2 Specifically excluded from this specification are autocatalytic, immersion, and vapor deposited gold coatings.

1.3 Gold coatings conforming to this specification are employed for their corrosion and tarnish resistance (including resistance to fretting corrosion and catalytic polymerization), bondability, low and stable contact resistance, solderability, and infrared reflectivity. Several types of coatings, differing in gold purity and hardness, are covered by this specification.

1.4 The values stated in SI units are to be regarded as the standard. Values provided in parentheses are for information only.

1.5 The following hazards caveat pertains only to the test methods section, Section 9, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B183 Practice for Preparation of Low-Carbon Steel for Electroplating

B242 Guide for Preparation of High-Carbon Steel for Electroplating

B253 Guide for Preparation of Aluminum Alloys for Electroplating

B254 Practice for Preparation of and Electroplating on Stainless Steel

B281 Practice for Preparation of Copper and Copper-Base Alloys for Electroplating and Conversion Coatings

B322 Guide for Cleaning Metals Prior to Electroplating

B343 Practice for Preparation of Nickel for Electroplating with Nickel

B374 Terminology Relating to Electroplating

B481 Practice for Preparation of Titanium and Titanium Alloys for Electroplating

B482 Practice for Preparation of Tungsten and Tungsten Alloys for Electroplating

B487 Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of Cross Section

B489 Practice for Bend Test for Ductility of Electrodeposited and Autocatalytically Deposited Metal Coatings on Metals

B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B504 Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method

B507 Practice for Design of Articles to Be Electroplated on Racks

B542 Terminology Relating to Electrical Contacts and Their Use

B558 Practice for Preparation of Nickel Alloys for Electroplating

B567 Test Method for Measurement of Coating Thickness by the Beta Backscatter Method

B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

B571 Practice for Qualitative Adhesion Testing of Metallic Coatings

B578 Test Method for Microhardness of Electroplated Coatings

B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

B678 Test Method for Solderability of Metallic-Coated Products

B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings

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[1] This specification is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatingsand is the direct responsibility of Subcommittee B08.04 on Precious Metal Coatings.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

B735 Test Method for Porosity in Gold Coatings on Metal Substrates by Nitric Acid Vapor

B741 Test Method for Porosity In Gold Coatings On Metal Substrates By Paper Electrography (Withdrawn 2005)[3]

B748 Test Method for Measurement of Thickness of Metallic Coatings by Measurement of Cross Section with a Scanning Electron Microscope

B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings

B765 Guide for Selection of Porosity and Gross Defect Tests for Electrodeposits and Related Metallic Coatings

B799 Test Method for Porosity in Gold and Palladium Coatings by Sulfurous Acid/Sulfur-Dioxide Vapor

B809 Test Method for Porosity in Metallic Coatings by Humid Sulfur Vapor (“Flowers-of-Sulfur”)

D1125 Test Methods for Electrical Conductivity and Resistivity of Water

D3951 Practice for Commercial Packaging

F390 Test Method for Sheet Resistance of Thin Metallic Films With a Collinear Four-Probe Array

2.2 *U.S. Government Standards:*[4]

MIL-DTL-45204 Gold Plating, Electrodeposited

MIL-STD-1916 DOD Preferred Methods for Acceptance of Product

2.3 *ANSI/ASQC Standard:*[5]

ANSI/ASQC Z1.4 Sampling Procedures and Tables for Inspection by Attributes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminologies B374 or B542, B374, and B542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *significant surfaces*—defined as those normally visible (directly or by reflection) or essential to the serviceability or function of the article. Can be the source of corrosion products or tarnish films that interfere with the function or desirable appearance of the article. The significant surfaces shall be indicated on the drawings of the parts or by the provision of suitably marked samples.

3.2.2 *underplating*—a metallic coating layer between the basis metal or substrate and the topmost metallic coating. The thickness of an underplating is usually greater than 1 µm (40 µin.), in contrast to a strike or flash, which is thinner.

4. Classification

4.1 *Types of Coatings*—A coating shall be specified by a combination of the following:

4.1.1 Type, characterizing minimum purity in accordance with 4.2.1,

4.1.2 Code, designating Knoop hardness in accordance with 4.2.3, and

4.1.3 a numeral designating thickness in micrometres in accordance with 4.3.

4.2 *Purity and Hardness:*

4.2.1 *Purity*—The issue of this standard establishes a new ASTM Type designation, which is identical to the original standard (MIL-G-45204, which is now MIL-DTL-45204), established for electrodeposited gold and is outlined in the following table.

Mass Percent Gold, Minimum, Excluding Potassium, Carbon & Nitrogen	New ASTM Type	MIL-DTL-45204 Type	Old ASTM Type
99.70	I	I	2
99.00	II	II	3
99.90	III	III	1

NOTE 1—It is commonly accepted that a gold purity of 99.7 % is defined as no more than 0.3 % of total codeposited metallic components, excluding potassium and sodium. Likewise, 99.9 % purity is recognized to mean no more than 0.1 % of total codeposited metal impurities, excluding potassium and sodium. Almost all gold electrodeposits will contain potassium, carbon and nitrogen that are occluded or precipitated in the deposit. In the case of Type I gold, the occluded potassium has been shown to improve durability and is desirable for that reason.[6,7]

4.2.2 Gold purity is calculated by subtraction of the sum of all non-gold metals in mass %, excluding potassium (K) and sodium (Na), from 100 %. The presence of Carbon (C), Nitrogen (N), Hydrogen (H), Na, and K contained in the electrodeposit are not included in the calculation.

4.2.3 *Hardness*—Hardness values shall be specified by ASTM Code. The military standard designation of Grade is included for reference.

Knoop Hardness Range	ASTM Code	MIL-DTL-45204 Grade
90 HK$_{25}$ maximum	A	A
91–129 HK$_{25}$	B	B
90–200 HK$_{25}$	(see Note 2)	. . .
130–200 HK$_{25}$	C	C
>200 HK$_{25}$	D	D

NOTE 2—ASTM Code B has previously been specified for hardness grade 90–200. This hardness grade has been eliminated and replaced with hardness grade 91–129 in accordance with MIL-DTL-45204.

4.2.4 *Relationship Between Purity and Hardness*—The following combinations of purity and hardness ranges are representative of good commercial practice:

New ASTM Type	Old ASTM Type	Code
I	2	A, B and C
II	3	B, C and D
III	1	A only

4.3 *Thickness*—Thickness shall be specified by an Arabic numeral that designates the minimum linear thickness in micrometres. Examples of commonly specified thicknesses are shown in Table 1.

4.3.1 See 7.4.2 for thickness tolerances.

4.3.2 Instead of specifying the thickness in micrometres, the purchaser may specify the mass of gold per unit area (coating weight) in milligrams per square centimeter. Unless otherwise specified, the density of gold is assumed to be 19.3 g/cm^3 for Type III and 17.5 g/cm^3 for Type I and Type II.

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[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Whitlaw, K. J., Souter, J. W., *Trans. Inst. Metal Fin.*, “The Role of Codeposited Elements in Gold Plated Contacts,” 1984, 62(1), pp. 29–31.

[7] Whitlaw, K. J., Souter, J., Wright, I.S., Nottingham, M., *Electrical Contacts*, “Wear Properties of High Speed Gold Electrodeposits,” (1984), 30th. pp. 33–45.

TABLE 1 Coating Thickness

Class	Minimum Thickness, µm
0.25	0.25
0.50	0.50
0.75	0.75
1.0	1.0
1.25	1.25
2.5	2.5
5.0	5.0

NOTE 3—The density of Type III gold coatings will be less than or equal to 19.3 g/cm^3, but not less than 18.5 g/cm^3.

NOTE 4—When significant surfaces are involved on which the specified thickness of deposit cannot readily be controlled, such as threads, holes, deep recesses, bases of angles, and similar areas, the purchaser and the supplier should recognize the necessity for either thicker deposits on the more accessible surfaces or for special racking. Special racks may involve the use of conforming, auxiliary, bipolar electrodes, or nonconducting shields.

5. Ordering Information

5.1 To make the application of this standard complete, the purchaser needs to supply the following information to the supplier in the purchase order or other governing document.

5.1.1 The name, designation, and date of issue of this specification.

5.1.2 Classification: Type, Code, and thickness (or mass per unit area) (see Section 4).

5.1.3 Presence and thickness of underplating, if required (see 3.2.2).

5.1.4 Significant surfaces shall be specified (see 3.2.1).

5.1.5 Requirement, if any, for performance testing such as porosity testing (see 9.6), solderability testing (see Appendix X4), ductility testing (see 9.7), etc.

5.1.6 If the substrate is one that requires a nickel underplating (see 6.5.1 and Appendix X6).

5.1.7 Whether or not stress relief has been or is to be done (steel parts only).

5.1.8 Sampling plan employed (see Section 8).

6. Manufacture

6.1 Any process that provides an electrodeposit capable of meeting the specified requirements is acceptable.

6.2 *Substrate:*

6.2.1 The surface condition of the basis metal should be specified and should meet this specification prior to the plating of the parts.

6.2.2 Defects in the surface of the basis metal such as scratches, porosity, pits, inclusions, roll and die marks, laps, cracks, burrs, cold shuts, and roughness may adversely affect the appearance and performance of the deposit, despite the observance of the best plating practice. Any such defects on significant surfaces shall be brought to the attention of the purchaser.

6.2.3 The basis metal shall be subject to such cleaning procedures as are necessary to ensure a satisfactory surface for subsequent electroplating (see Practices B183, B242, Guide B253, Practices B254, B281, B322, B343, B481, B482, and B558).

6.2.4 Proper preparatory procedures and thorough cleaning of the basis metal are essential for satisfactory adhesion and performance of these coatings. The surface must be chemically clean and continuously conductive, that is, without inclusions or other contaminants. They must be smooth and as free of scratches, gouges, nicks, and similar imperfections as possible.

NOTE 5—A metal finisher can often remove defects through special treatments such as grinding, polishing, abrasive blasting, chemical treatments, and electropolishing. However, these may not be normal in the treatment steps preceding the plating and a special agreement is indicated.

6.3 If required (see 5.1.7), steel parts with a hardness greater than 31 HRC shall be given a suitable stress relief heat treatment prior to plating. Such stress relief shall not reduce the hardness to a value below the specified minimum. Acid pickling of high strength steels shall be avoided.

6.3.1 The coating shall be applied after all basis metal heat treatments and mechanical operations on significant surfaces have been completed.

6.4 *Racking*—Parts should be positioned so as to allow free circulation of solution over all surfaces. The location of rack or wire marks in the coating shall be agreed upon between the purchaser and the supplier.

6.5 *Plating Process:*

6.5.1 *Nickel Underplating*—For thickness Classes except 5.0, a nickel underplating shall be applied before the gold coating when the product is made from copper or copper alloy. Nickel underplatings are also applied for other reasons (see Appendix X6).

NOTE 6—When the thickness of the nickel underplate has a detrimental impact on the mechanical properties or bondability of the substrate, the nickel thickness may be reduced to a non-detrimental level as specified by the purchaser.

NOTE 7—In certain instances in which high-frequency analog signals are employed, such as in wave guides, the magnetic properties of nickel may attenuate the signal.

NOTE 8—In applications in which forming or flaring operations are to be applied to the plated component, a ductile nickel electrodeposit should be specified.

6.5.2 *Strikes*—It is recommended to apply a gold strike to the underplate or substrate, except if the latter is silver or platinum, prior to applying the gold top coating.

6.5.3 *Plating*—Good practice calls for parts to be electrically connected when entering the gold plating solution. A minimum of 0.5 V is suggested.

NOTE 9—For rack and barrel plating processing, residual plating salts can be removed from the articles by a clean, hot (50 to 100°C) water rinse. A minimum rinse time of 2.5 min (rack) or 5 min (barrel) is suggested. Best practice calls for a minimum of three dragout rinses and one running rinse with dwell times of 40 s in each station when rack plating and 80 s when barrel plating. Modern, high-velocity impingement-type rinses can reduce this time to a few seconds. This is particularly useful in automatic reel-to-reel applications in which dwell times are significantly reduced.

7. Coating Requirements

7.1 *Nature of Coating*—The gold deposit shall meet the appropriate purity requirements as put forth in the following:

7.1.1 Type I coatings shall contain at least 99.70 mass % gold, excluding potassium, sodium, carbon and nitrogen. For Type I Code A ("soft") coatings only, metallic hardening agents such as nickel, cobalt or iron combined, shall be less than 0.05 mass % and none of these three elements shall be present in an amount greater than 0.03 mass %. All other metals excluding potassium and sodium are considered impurities and shall not be present in amounts greater than 0.05 mass % combined. For Type I Code B and C coatings, metallic hardening agents such as nickel, cobalt or iron combined shall be equal to or less than 0.3 mass %. All other metals are considered impurities and shall not be present in amounts greater than 0.05 mass % each, 0.1 % combined. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.1.2 Type II coatings shall contain at least 99.00 mass % gold, excluding potassium, sodium, carbon and nitrogen. Type II coatings may contain metallic hardening agents, such as nickel, cobalt or iron, which may be present in amounts greater than 0.3 mass %. All other metals, excluding potassium and nitrogen, shall be considered impurities and shall not be present in amounts greater than 0.1 mass % each. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.1.3 Type III coatings shall contain at least 99.90 mass % gold, excluding potassium, sodium, carbon and nitrogen. Individual metal impurities shall not be present in a quantity greater than 0.04 mass %. Iron, nickel and cobalt combined shall be less than 0.05 mass %, and none of these three elements shall be present in an amount greater than 0.03 mass %. All non-gold metals, excluding potassium and sodium, are considered impurities and shall not be present in amounts greater than 0.1 mass % combined. The gold purity shall be calculated by determining the content of all non-gold metals in mass % (except potassium and sodium) and subtracting this value from 100 %.

7.2 *Hardness*—The gold coating shall have a Knoop hardness within the specified range as shown in 4.2.3 when tested in accordance with 9.2.

7.3 *Appearance*—Gold coatings shall be coherent, continuous, and have a uniform appearance to the extent that the nature of the basis metal and good commercial practices permit.

7.4 *Thickness:*

7.4.1 The gold coating shall have a thickness on the significant surfaces in accordance with 4.3 unless otherwise specified.

NOTE 10—Where Type I (Code B or C) or Type II (Code B or C) gold is specified, improved protection of the underlying metals can be obtained by applying a duplex gold composite coating consisting of an underlying layer of Type III (Code A) gold. Typical thicknesses of the Type III gold underlayer are 10 to 30 % of the total specified thickness. However, care must be taken to ensure that the thickness of the Type I or Type II gold topcoat is sufficient so as not to compromise wear properties. When measuring the total gold thickness of duplex composite coatings, a density of 17.5 g/cm^3 should be employed (see 9.4).

7.4.2 The thickness of the gold coating shall be equal to or exceed the specified thickness throughout the significant surface (see 3.2.1). When plated parts are used in mating applications, the maximum thickness shall not exceed the tolerance specified for the part on its engineering drawing. It is customary that allowance for plated coatings be included within the part tolerance.

NOTE 11—The coating thickness requirement of this specification is a minimum requirement: that is, the coating thickness is required to equal or exceed the specified thickness throughout the significant surfaces, while conforming to all maximum allowed thicknesses created by part dimensional tolerances given in the engineering drawing. Variation in the coating thickness from point to point on a coated article is an inherent characteristic of electroplating processes. Therefore, the coating thickness at any single point on the significant surface will sometimes have to exceed the specified value in order to ensure that the thickness equals or exceeds the specified value at all points. Hence, most average coating thicknesses will be greater than the specified value; how much greater is largely determined by the shape of the article (see Practice B507) and the characteristics of the plating process. In addition, the average coating thickness on articles will vary from article to article within a production lot. Therefore, if all the articles in a production lot are to meet the thickness requirement, the average coating thickness for the production lot as a whole will be greater than the average necessary to ensure that any single article meets the requirement (see 8.1).

7.5 *Adhesion*—The gold coatings shall be adherent to the substrate when tested by one of the procedures summarized in 9.5.

7.6 *Integrity of the Coating:*

7.6.1 *Gross Defects/Mechanical Damage*—The coatings shall be free of visible mechanical damage and similar gross defects when viewed at magnifications up to 10×. For some applications this requirement may be relaxed to allow for a small number of such defects (per unit area), especially if they are outside or on the periphery of the significant surfaces (see 7.6.2).

7.6.2 *Porosity*—Almost all as-plated electrodeposits contain some porosity. The tolerable amount of porosity in the coating depends on the severity of the environment that the article is likely to encounter during service or storage. If the pores are few in number or away from the significant surfaces, their presence can often be tolerated. Such acceptance (or pass-fail) criteria, if required, shall be part of the product specification for the particular article or coating requiring the porosity test (see 9.6 for porosity testing).

8. Sampling

8.1 The supplier is urged to employ statistical process control in the coating process. Properly performed, this process will ensure coated products of satisfactory quality and will reduce the amount of acceptance inspection. The sampling plan used for the inspection of the quality of the coated articles shall be as agreed upon between the purchaser and the supplier.

NOTE 12—Usually, with a collection of coated articles, the inspection lot (see 8.2) is examined for compliance with the requirements placed on the articles, a relatively small number of the articles, the sample, is selected at random and is inspected. The inspection lot is then classified as complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria of compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B602, Guide B697, and Test Method B762 contain sampling plans that are designed for the sampling inspection of coatings. Test Method B602 contains four sampling plans, three for use with tests that are nondestructive and one with those that are destructive. The purchaser and supplier may agree on the plan or plans to be used. If they do not, Test Method B602 identifies the plan to be used. Guide B697 provides a large number of plans and also gives guidance in the selection of a plan. When Guide B697 is specified, the purchaser and supplier need to agree on the plan to be used. Test Method B762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numerical value and certain statistical requirements must be met. Test Method B762 contains several plans and also gives instructions for calculating plans to meet special needs. The purchaser and supplier may agree on the plan or plans to be used. If they do not, Test Method B762 identifies the plan to be used.

8.2 An inspection lot shall be defined as a collection of coated articles that are of the same kind; that have been produced to the same specifications; that have been coated by a single supplier at one time, or at approximately the same time; under essentially identical conditions; and that are submitted for acceptance or rejection as a group.

9. Test Methods

9.1 *Deposit Purity*—Use any recognized method to determine quantitatively the metallic impurities present. Atomic absorption spectrophotometry (or any methods with demonstrated uncertainty less than 10 %) may be used to determine the metallic impurities. Initial scanning should be carried out for all elements in order to detect any unknown or unexpected metallic impurities. Determine deposit purity by subtracting total impurities in mass from 100 %. Deposit purity should be determined on samples at plating conditions representative of actual production.

9.2 *Hardness*—Measure hardness in accordance with Test Method B578. Deposit hardness should be determined on samples at plating conditions representative of actual production.

9.3 *Appearance*—The coating shall be examined at magnifications up to 10× for conformance to the requirements of appearance.

9.4 *Thickness and Mass per Unit Area*—Measure thickness by methods outlined in Test Methods B487, B567, B568, or B748. The method chosen shall be such as to give an uncertainty of less than 10 % on the particular coating being measured.

9.4.1 *Thickness*—The beta backscatter, X-ray fluorescence spectrometry, and coulometric methods measure the mass of gold per unit area that is present over the measured area. The cross-sectioning and magnetic methods measure the geometrical thickness of the gold present. Since many gold coatings have a density lower than the theoretical density of gold (19.3 g/cm^3), instruments utilizing the measuring principles in Test Methods B504, B567, and B568 will often give lower readings than the microscopical cross-section method. To convert mass of gold per unit area that is present over the measured area to a geometrical thickness, it is necessary to use standards having a density identical to that of the coatings to be measured, or to multiply the reading obtained by factor, *f*.

$$f = \frac{19.3}{d} \tag{1}$$

where:

d = density of gold coating, g/cm^3.

9.4.1.1 The density of gold coatings depends not only on the type of gold coating but also on the gold content and the composition and purity of the electroplating solution. The density figure, when the above methods are used for measurements of thickness, shall be considered to be 19.3 g/cm^3 for Type III coatings and 17.5 g/cm^3 for Type I and Type II coatings, unless:

(*1*) the density is supplied by the plating process vendor, or

(*2*) the density has been measured.

9.4.2 *Mass Per Unit Area*—Test Methods B504, B567, and B568 measure the mass of gold per unit area (coating weight) directly and independently of the density of gold.

NOTE 13—The calibration standards available from the National Institute of Standards and Technology (NIST)[8] are certified in units of mass of gold per unit area. Other calibration standards for gold are generally certified in thickness units that can be converted to mass per unit area units by multiplying by the density of pure gold.

$$\text{Mass per unit area (or coating weight)} \tag{2}$$

$$\text{in mg/cm}^2 = 19.3 \times \text{thickness } (\mu\text{m})/10$$

This conversion should be verified by the supplier of the calibration standards.

9.5 *Adhesion*—Determine adhesion by one of the following procedures (see Practice B571 for full details).

9.5.1 *Bend Test*—Bend the electroplated article repeatedly through an angle of 180° on a diameter equal to the thickness of the article until fracture of the basis metal occurs. Examine the fracture at a magnification of 10×. Cracking without separation does not indicate poor adhesion unless the coating can be peeled back with a sharp instrument.

9.5.2 *Heat Test*—No flaking, blistering, or peeling shall be apparent at a magnification of 10× after the gold electroplated parts are heated to 300 to 350°C (570 to 660°F) for 30 min and allowed to cool.

9.5.3 *Cutting Test*—Make a cut with a sharp instrument and then probe with a sharp point and examine at a magnification of 10×. No separation of the coating from the substrate shall occur.

9.6 *Plating Integrity*—Porosity shall be determined preferably by either Test Method B735, B741, B799, or B809 unless otherwise specified. See Guide B765 for guidelines for selecting the appropriate test method.

NOTE 14—The test to be selected will depend upon the gold thickness, the nature of the basis metal, the nature and thickness of any intermediate layers or underplate, the shape of the gold-coated part, and its intended service environment.

9.7 *Ductility*—When required, determine ductility in accordance with Practice B489.

10. Special Government Requirements

10.1 The following special requirements shall apply when the ultimate purchaser is the U.S. Government or an agent of the U.S. Government.

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[8] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

10.1.1 *Sampling*—For government acceptance, the sampling plans specified in MIL-STD-1916 or ANSI/ASQC Z1.4 are to be used instead of the ASTM standards specified in 8.1.

10.1.2 *Thickness Testing:*

10.1.2.1 In addition to the nondestructive method outlined in Test Methods B499, B567, and B568, a cross-sectioning method, such as that specified by Test Method B487 or B748, can also be used as a referee method to confirm the precision and bias of the particular non-destructive technique when thicknesses of 0.75 µm or above are used.

10.1.2.2 The part shall be covered with gold. The gold thickness on significant surfaces shall be at least 1.25 µm (50 µin.), unless otherwise specified in the drawings or contract. Any specific requirement for thicknesses on non-significant surfaces shall be agreed on between purchaser and supplier.

10.1.3 *Packaging*—Parts plated for the U.S. Government and Military, including as subcontracts, shall be packaged in accordance with Practice D3951.

11. Keywords

11.1 engineering coatings; engineering gold; gold; gold coatings; gold electrodeposits; gold platings; underplate

APPENDIXES

(Nonmandatory Information)

X1. TYPICAL USES

X1.1 The conditions of exposure and the uses of gold coatings are so varied that it is often not possible to predict the life of a coating of a given thickness and hardness. Some typical uses of gold coatings are enumerated below, but the list is not complete and is intended for general guidance only.

X1.1.1 *Type III, Code A Gold*—For semiconductor components, nuclear engineering, thermocompression bonding, thermosonic bonding, ultrasonic bonding, solderability, and high-temperature applications.

X1.1.2 *Type I*—For general-purpose, high-reliability electrical contacts, and wire wrap connections.

X1.1.3 *Type II, General-Purpose Wear Resistant Gold*—Will not withstand high-temperature applications because the hardening agents in the gold coating will oxidize.

X1.1.4 *Solderability*—*Type III* golds are preferred for solder applications. Oxidation of co-deposited metals can make soldering more difficult. It is strongly recommended that gold coating thicknesses not exceed 0.5 µm for solder applications. There is evidence to show that when the gold content in the tin-lead solder joint exceeds about 3 % by weight, embrittlement occurs leading to potential solder joint failure.[9]

X1.1.5 *Printed Wiring Boards*—Boards that will be sheared or cropped should not be electroplated with a heavy thickness of a hard gold because of possible cracking of the gold. Coatings with purities of 99.0 to 99.7 % are used with B or C hardness and at thicknesses generally not in excess of 2.5 µm.

X1.1.6 *Static Separable Connectors*—Coatings at any of the listed purities and with hardnesses A, B, or C are used to any thickness up to 5 µm. Selection of the type and thickness of the gold coating is determined by the desired life in the operating environment of the electroplated component.

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[9] Glazer, J., Kramer, P. A., and Morris, J. W., Jr., "Effect of Au on the Reliability of Fine Pitch Surface Mount Solder Joints," *Proceedings from Surface Mount International Conference and Exposition*, August 25–29, pp. 629–639.

X2. RESISTIVITY

X2.1 When electrodeposited gold coatings are used as electrical conductor paths, the electroplating process can be expected to produce coatings having maximum resistivities as specified in Table X2.1.

X2.2 Use any reliable four-point probe method for determining resistivity of gold coatings. A suggested four-point method is detailed in Test Method F390.

TABLE X2.1 Maximum Electrical Sheet Resistivity by the Four Point Probe Method[A]

Gold Finishes	Ohm per Square
A and B	0.03
C	0.10

[A] When the electroplated coatings are used as electrical conductor paths, the sheet resistance in ohms per square should be specified and not the coating thickness.

X3. RESIDUAL SALTS

X3.1 Electroplated parts are placed in water of known conductivity and agitated for a specific time. The conductivity of the water extract is measured, and the increase in conductivity due to residual salts and other conducting impurities is calculated. A suggested water extract conductivity test method uses a procedure in accordance with Test Methods D1125, Method A.

X3.2 Conductivity of water for extract test shall be 1 µS/cm or less (resistivity 1 MΩ·cm or more).

X3.2.1 A sample of the coated parts having a total surface area of 30 cm^3 shall ordinarily be used and extracted in 100 cm^3 of equilibrated water. To prepare equilibrated water, fill a clean polyethylene bottle half-way with high-purity water (X3.1), replace the bottle cap, and shake the bottle vigorously for 2 min to equilibrate the water with the carbon dioxide (CO_2) in the air. CO_2 is a component of air. It is soluble in water and forms carbonic acid that ionizes and is at equilibrium at 0.8 µS/cm. Slowly agitate the solution for 10 min before determining the conductivity of the extract. In a closed polyethylene bottle, the equilibrated water will remain in the range from 0.8 to 1 µS/cm for at least 1 week. Place the specimen in the bottle in accordance with X3.1.

X3.3 Inspection under a source of ultraviolet light is often employed to determine whether electroplating salts have been removed by the rinsing following gold electroplating. The presence of salts is evidenced by a characteristic fluorescence and should not be confused with fluorescing dirt or dirt particles.

X3.4 Water or purging stains, resulting from blind holes or from parts that were assembled before electroplating, as normally obtained in good commercial practice, are permissible, except where they occur on surfaces to which electrical contact is to be made or on which subsequent soldering operations are performed.

X4. SOLDERABILITY

X4.1 Where solderability requirements are specified, solderability testing shall be done in accordance with Test Method B678.

X5. MANUFACTURE

X5.1 *Substrate Preparation:*

X5.1.1 Practices B183, B242, B253, B254, B281, B322, B343, B481, and B482 should be used where appropriate for the preparation of the applicable basis metal.

X5.1.2 When electroplated materials are used for electrical contacts, cleaning alone may not properly prepare the surface for gold electroplating. If the basis metal is scratched or rough, it may be necessary to level the surface by processes such as electropolishing, chemical polishing, or the application of a self-leveling nickel or copper undercoating before gold electroplating. However, the use of these undercoatings requires the approval of the purchaser.

X5.2 *Underplatings:*

X5.2.1 Silver shall not be used as an underplating unless specified by the purchaser.

X5.2.2 Copper alloys containing zinc, beryllium, tellurium, or lead should be precoated to prevent adhesion problems. If copper or nickel underplatings are used, they should have a nominal thickness of at least 1.2 µm. Thickness of the underplating should be consistent with end-use requirements. With cyanide-sensitive copper alloys, such as those containing beryllium or tellurium, an acid copper strike is recommended.

X5.2.3 Gold coatings on zinc, aluminum, steel, and other metals normally require underplatings such as copper or nickel of sufficient thickness to impact adequate corrosion protection to the basis metal.

X5.2.4 To minimize diffusion, a nickel underplating with a nominal thickness of at least 1.2 µm should be applied before depositing any of these gold finishes on copper and copper alloy parts that can be subjected to elevated temperatures. The thickness of the underplating should be consistent with end-use requirements (see 6.5.1).

X5.2.5 A gold strike is often used to precede the final gold coating, to improve adhesion, and to prevent contamination of the main gold electroplating solution with metallic impurities.

X5.3 *Gold Electrolytes*—Most gold electroplating solutions used for producing these coatings are proprietary. Any bath that produces coatings meeting the requirements of the specification may be used.

X5.3.1 *Solution Contamination*—Care should be exercised to prevent contamination of gold electroplating solutions with organic or metallic impurities. Copper, zinc, cadmium (from racking materials, bus bars, etc.), iron (from insoluble anodes), lead and tin (from solder parts), and silver (from impurities in the electroplating bath makeup salts) are some of the more common contaminants, which, if present in the coating in more than trace quantities, can have harmful effects on such properties as hardness, solderability, and porosity.

X5.3.2 *Activated Carbon Treatment*—Periodic treatment of the solution with activated carbon is recommended to control the buildup of organic impurities. This contamination can have the effect of producing discoloration of the deposit. Thus, the appearance of test coupons may serve as an indication of an approaching need for the activated carbon treatment. (**Warning—**Do not store activated carbon in areas in which vapors from solvents and other chemicals may contaminate the carbon.)

X5.3.3 *Control of the Gold Electroplating Bath*—Under continuous operations, when control of bath composition can be readily established by scheduled additions, analyses of the electroplating bath constituents should be made on a regularly scheduled basis. When the work load is erratic, each addition should be based on bath analyses.

X5.3.4 *Control of the Gold Deposit*—The adhesion, hardness, and composition of the gold deposit should be determined on a regularly scheduled basis. Once it has been established that the co-deposited metallic impurity limitations are being continuously met in production, frequency of determination can be reduced. Appearance, porosity, and thickness should be determined often enough to ensure compliance with specific requirements.

X6. SOME REASONS FOR USING A NICKEL UNDERPLATE

X6.1 *Diffusion Barrier:*

X6.1.1 To inhibit diffusion of copper from the basis metal (and of zinc from brass) to the surface of the precious metal plating.

X6.1.2 To inhibit interdiffusion between the basis metal and the gold top coat (for example, silver and copper), which might produce a weak alloy or intermetallic compound at the interface.

X6.2 *Levelling Layer*—To produce a smoother surface than the basis metal in order to ensure a lower porosity gold top plate (for example, levelling nickel over a rough substrate).

X6.3 *Pore Corrosion Inhibitor*—A nickel underplate under the gold top coat will form passive oxides at the base of pores in humid air, provided the environment does not contain significant amounts of acidic pollutants (such as sulfur dioxide (SO_2) or hydrogen chloride (HCl)).

X6.4 *Tarnish Creepage Inhibitor for Gold*—Non-copper base metals will inhibit creepage of copper tarnish films over the gold—where the tarnish originates from pores and bare copper edges.

X6.5 *Load-Bearing Underlayer for Contacting Surfaces*—A hard nickel underplate can serve as a load-bearing foundation for the gold top coat to prevent cracking of hard golds and reduce the wear of the precious metal during sliding of the contacting surfaces.